US010572761B1

(12) **United States Patent**
Bastani et al.

(10) **Patent No.: US 10,572,761 B1**
(45) **Date of Patent: Feb. 25, 2020**

(54) **VIRTUAL REALITY SYSTEM USING SUPER-RESOLUTION**

(71) Applicant: **GOOGLE LLC**, Mountain View, CA (US)

(72) Inventors: **Behnam Bastani**, San Jose, CA (US); **Eliezer Peli**, Needham, MA (US)

(73) Assignee: **GOOGLE LLC**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 88 days.

(21) Appl. No.: **15/997,891**

(22) Filed: **Jun. 5, 2018**

Related U.S. Application Data

(60) Provisional application No. 62/515,114, filed on Jun. 5, 2017.

(51) **Int. Cl.**

G06K 9/40	(2006.01)
G06T 5/00	(2006.01)
G06T 19/00	(2011.01)
G06T 3/40	(2006.01)

(52) **U.S. Cl.**
CPC ***G06K 9/40*** (2013.01); ***G06T 3/4053*** (2013.01); ***G06T 5/002*** (2013.01); ***G06T 19/006*** (2013.01)

(58) **Field of Classification Search**
CPC G06F 3/017; G06F 1/163; G06F 3/011; G02B 2027/0134; G02B 27/017
USPC 382/264; 345/419; 348/51, 745, 43, 348/E13.068
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

9,535,249	B2 *	1/2017	Takeda	G02B 27/017
10,168,798	B2 *	1/2019	Tsang	G06F 3/02
10,229,540	B2 *	3/2019	Bavor, Jr.	G06F 3/013
10,452,227	B1 *	10/2019	Philbrick	G06T 19/003
2011/0169824	A1 *	7/2011	Fujinami	G09G 3/003 345/419
2013/0147911	A1 *	6/2013	Karsch	H04N 13/261 348/43
2014/0340492	A1 *	11/2014	Abe	H04N 9/3188 348/51
2017/0078645	A1 *	3/2017	Aurigema	H04N 13/254
2017/0180780	A1 *	6/2017	Jeffries	H04N 21/4307

* cited by examiner

Primary Examiner — Charlotte M Baker
(74) *Attorney, Agent, or Firm* — Brake Hughes Bellermann LLP

(57) **ABSTRACT**

Displaying video in an HMD may include introducing unperceived noise to the video frame signal in order to enhance dynamic range. For example, each of a viewer's left and right eyes have a field of view (FOV) corresponding to a portion of pixels shown on the HMD. For each of these portions of pixels, the VR system may combine a noise signal (e.g., zero-mean Gaussian white noise) with the video signals corresponding to each of the portions of pixels. The introduction of such noise may improve the dynamic range of the viewer. Further, in some implementations, the noise signal that is combined with the left video signal may be slightly different from the noise signal that is combined with the right video signal. Such slightly different noise signals may provide further improvement to the image seen by the viewer due to binocular summation.

20 Claims, 7 Drawing Sheets